TS 2004 NDT Workshop

Ground Penetrating Radar for Pavement Investigations

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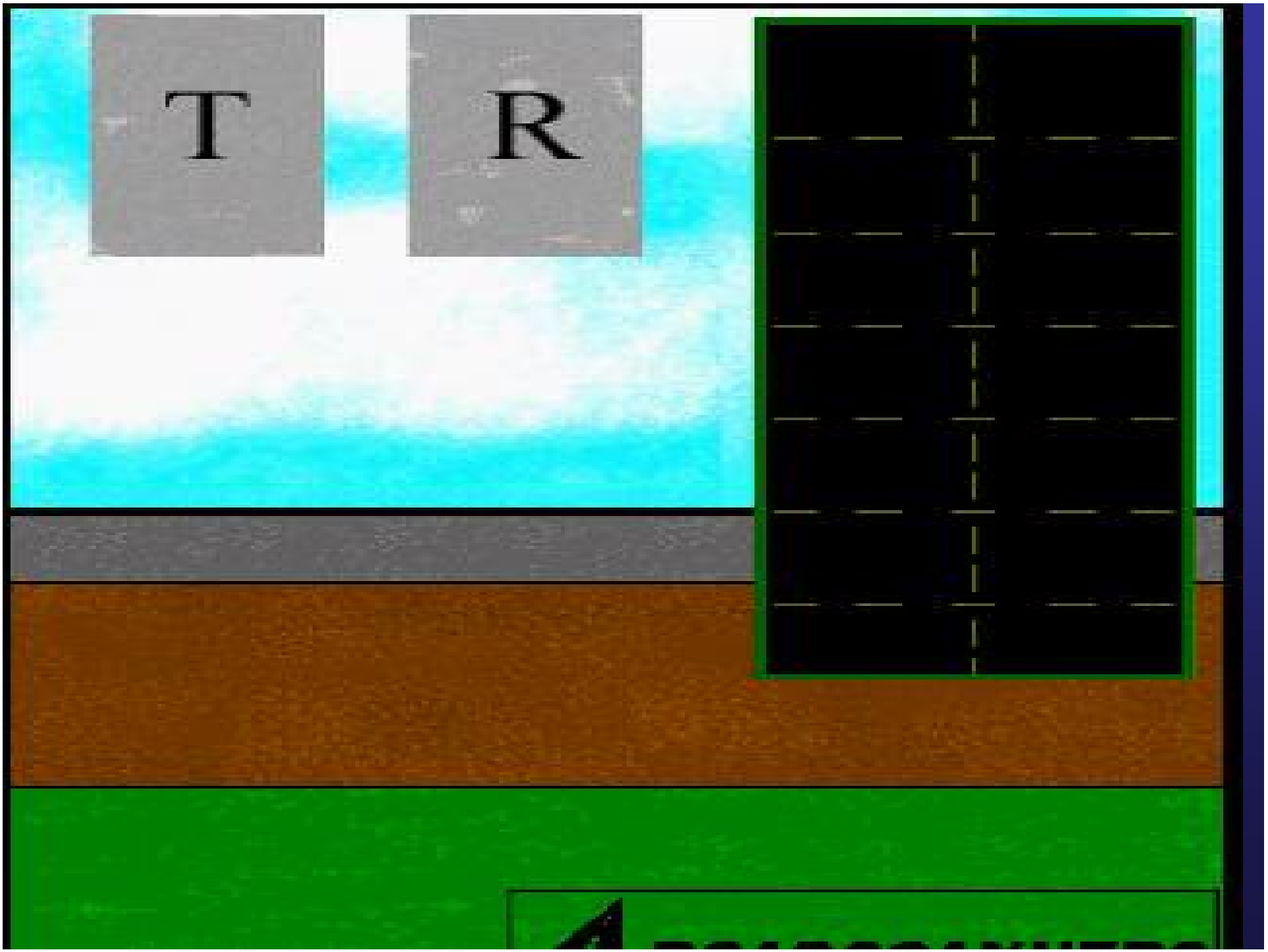
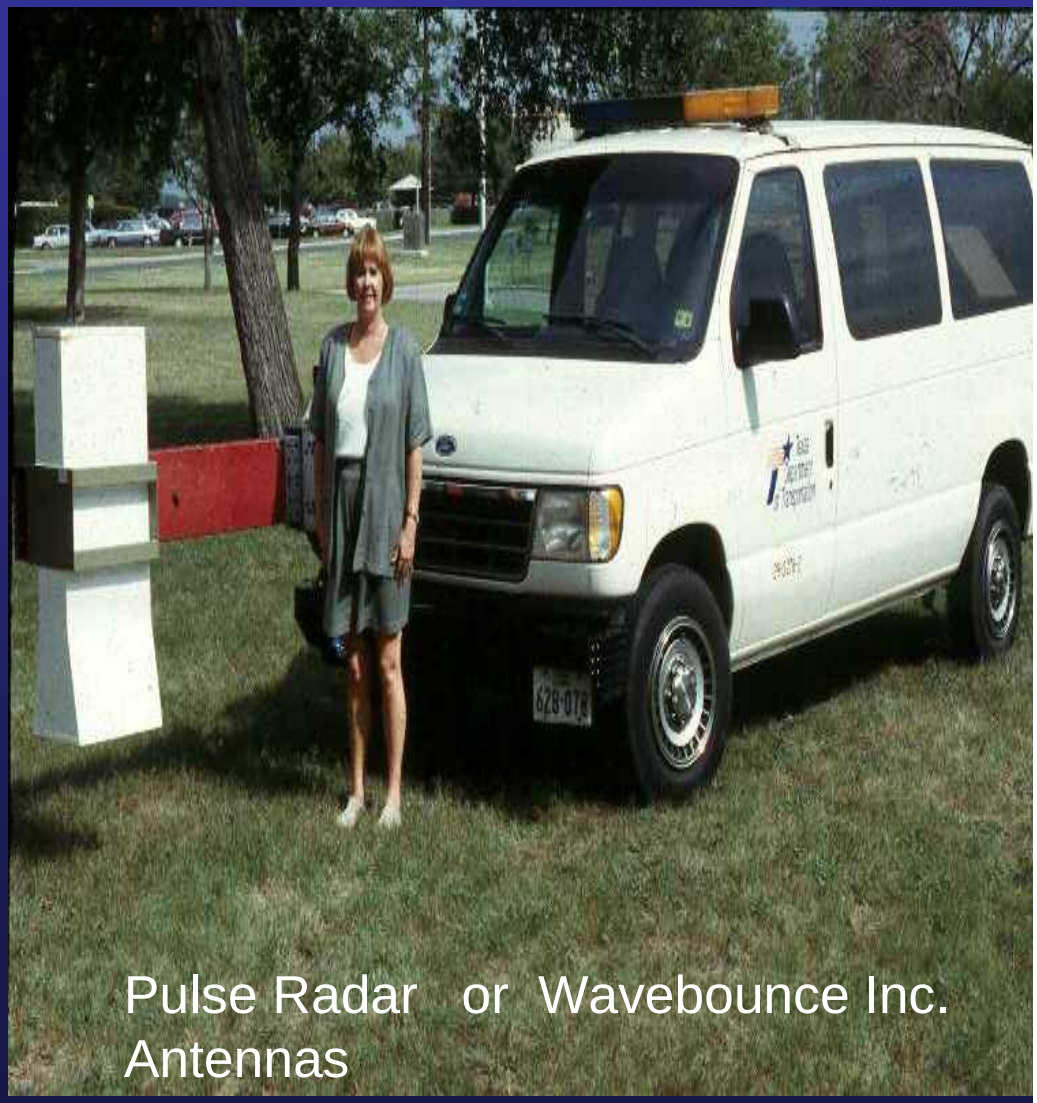
Overview of GPR Workshop

- 1 What is GPR ?
- 2 History of GPR within TxDOT
- 3 Field Data Collection + Analysis
- 4 Successful Applications in Texas
- 5 Key Steps in Implementation


T
R

TxDOT's Ground Penetrating Radar Unit

- TTI's data acquisition and processing systems (COLORMAP)
- Integrated Video
- Data collected at highway speed (60 mph)
- Effective depth of penetration 24 ins
- TxDOT has 5 available units (Austin, Fort Worth, TTI, Odessa and Bryan)
- TxDOT Contact: Carl Bertrand



Pulse Radar or Wavebounce Inc. Antennas

Florida's GPR unit

- Contact: Tom.Byron@dot.state.fl.us

- Applications
  - Checking layer thickness for PMS (within 0.5" HMA, base variable)
  - Toll road surveys
  - Move to project level

Pulse Radar Antenna

Finland's GPR systems

- Similar units in Missouri, Kentucky and Indiana

- Contacts

Timo.Saarenketo @roadscanners.com

John Wenzlick, MoDOT

GSSI Antenna

TxDOT's GPR Development Effort

- 87 - 88 GPR first demonstrated to TxDOT
- 89 - 90 Evaluation + Specifications Development
- 90 - 99 Software Development- Research system purchased - numerous research studies
- 95 – 96 TxDOT purchases first system
- 96 – 03 Training schools
- 01 – 02 Buy additional units
- 01 – 04 Quality Control Studies
- 02 – 04 Integrating GPR and FWD

TxDOT's Specification Tests

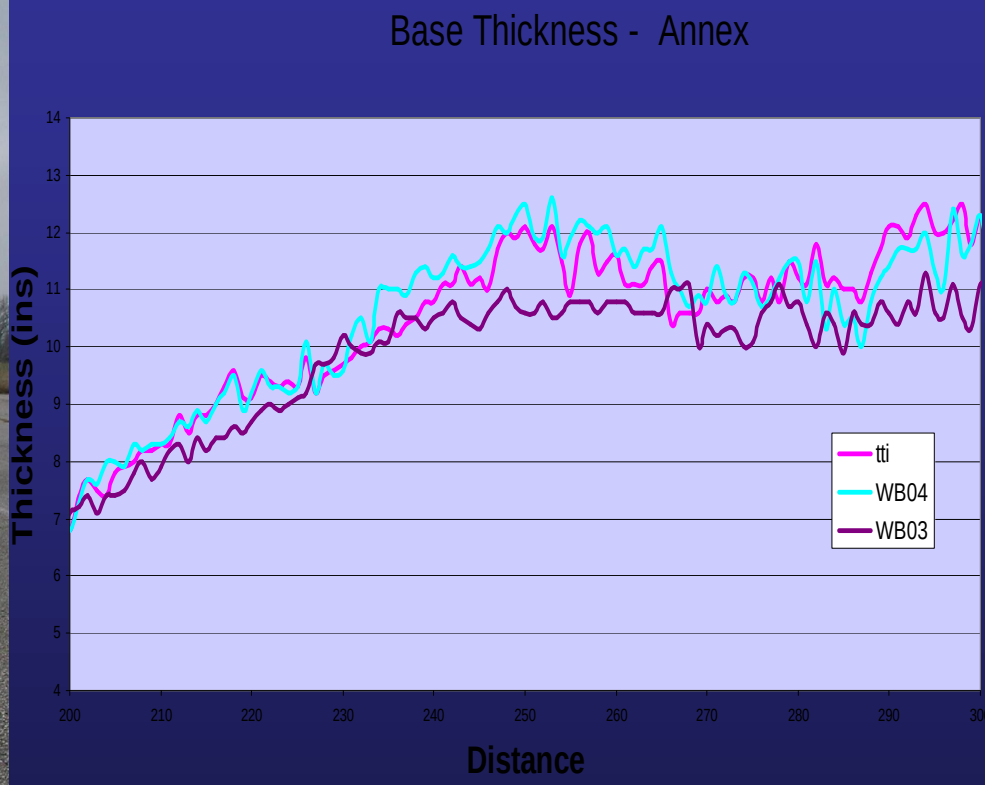
Annual Recalibrations (completed May 2003)

Standard tests include

- Noise/Signal < 5%
- Signal stability < 1%
- Long term Stab < 3%
- Concrete Penetration
- System Calibration factors determined

6 Units tested (May 2003)

Repeatability studies at TTI Annex



FIELD DATA COLLECTION

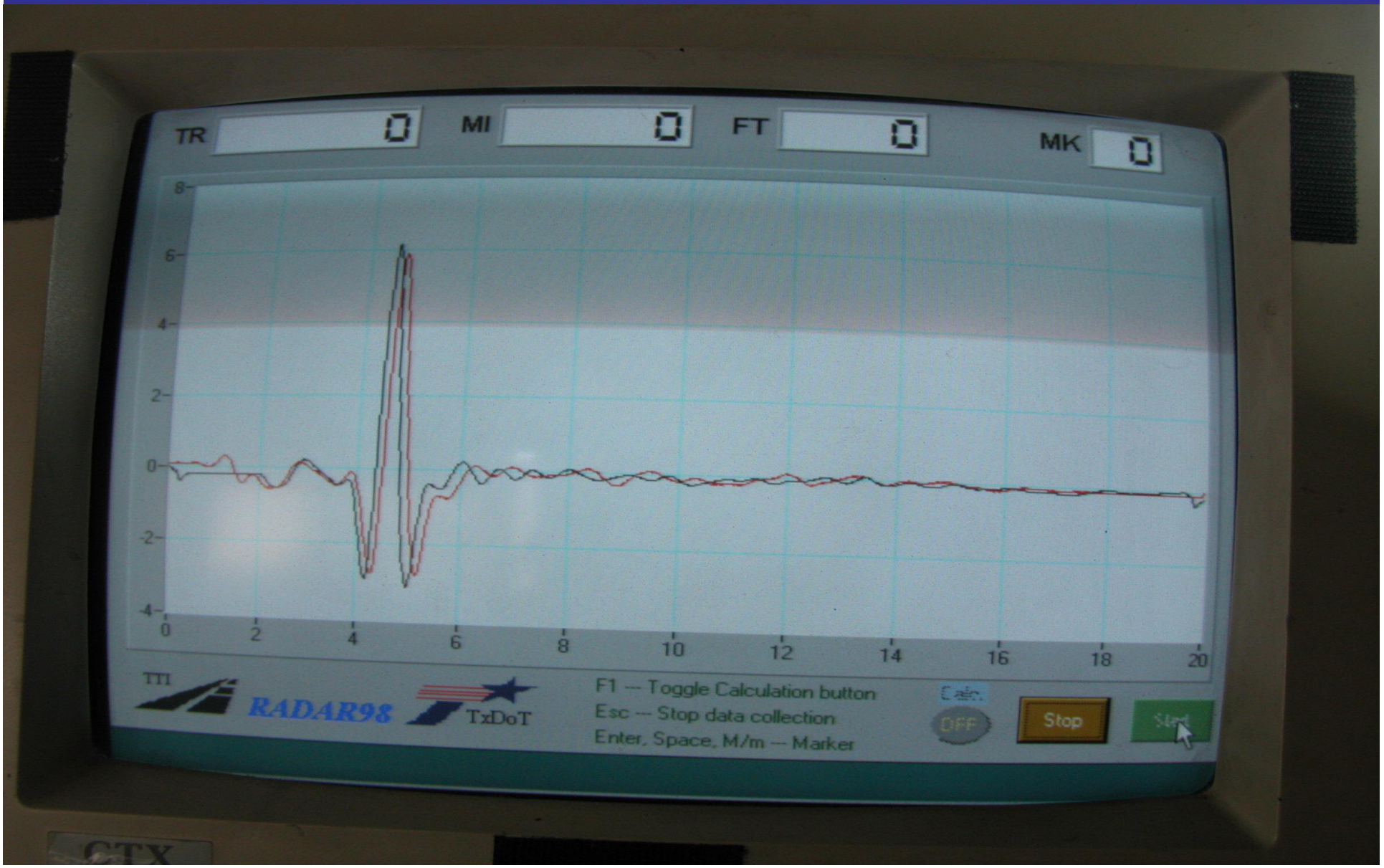
Mounting GPR equipment

Fiberglass Boom

Cable connections

Final Assembly 15 minute warm up

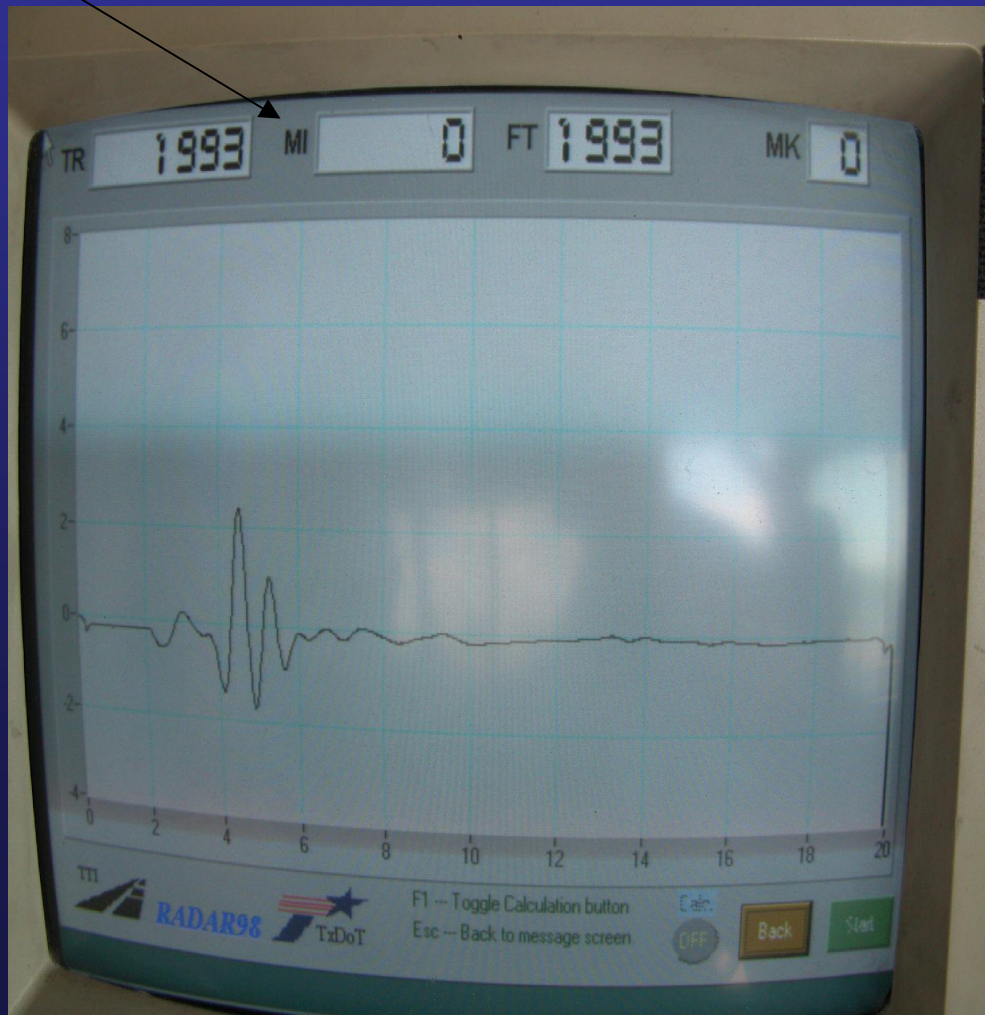
Step 1 Data Acquisition System Check



Data Acquisition TTI's RADAR 2K program

Operators view during data collection

same header information



Metal Plate Test at end of run

Data Collection Recommendations

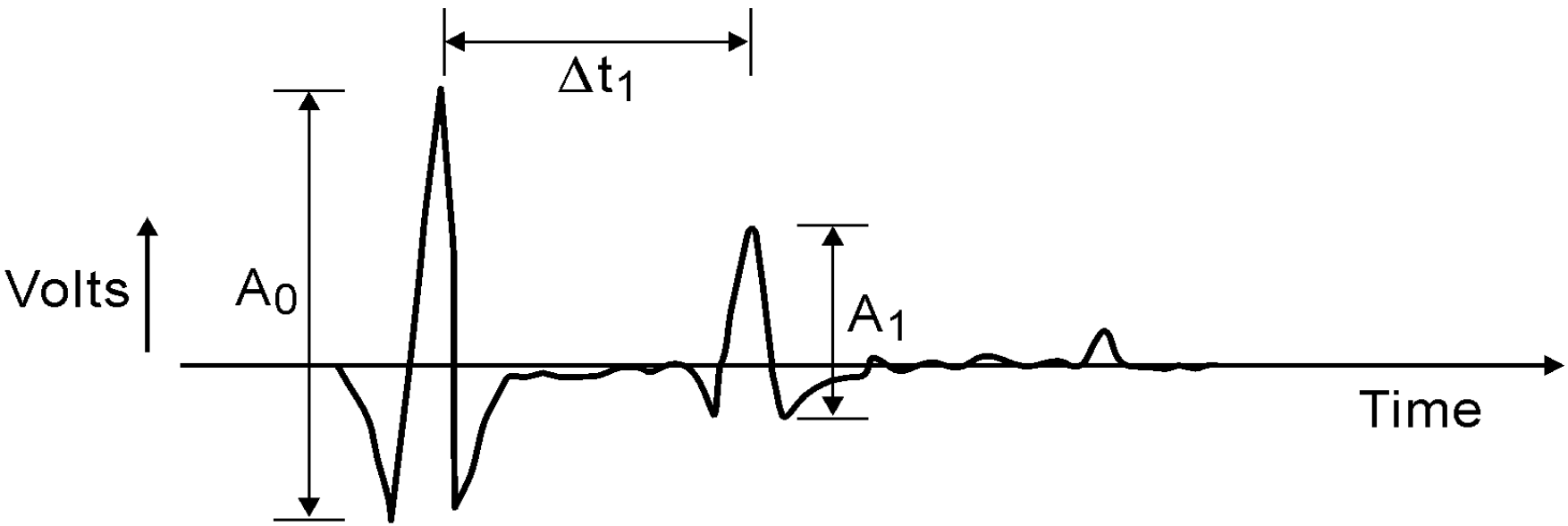
- 2 person operation (driver/operator)
- High Speed: 200 miles/day; Integrated Video/GPR essential
- Data Resolution 1024 points per trace
- Mostly Outside lane/ Outside wheel path
  - Depends on application
  - Multiple passes, transverse, slalom
- Distance driven data collection
  - Interval depends on application
- Operator Notes
  - Power lines, reference markers in data
  - Written notes on each marker and start/stop of major distresses
- Weather Restriction
  - Standing water
  - Equipment damaged by rain
- Verification cores critical on older sections

TTI's Rut/Ride Calibration section

Interpretation of GPR Signals

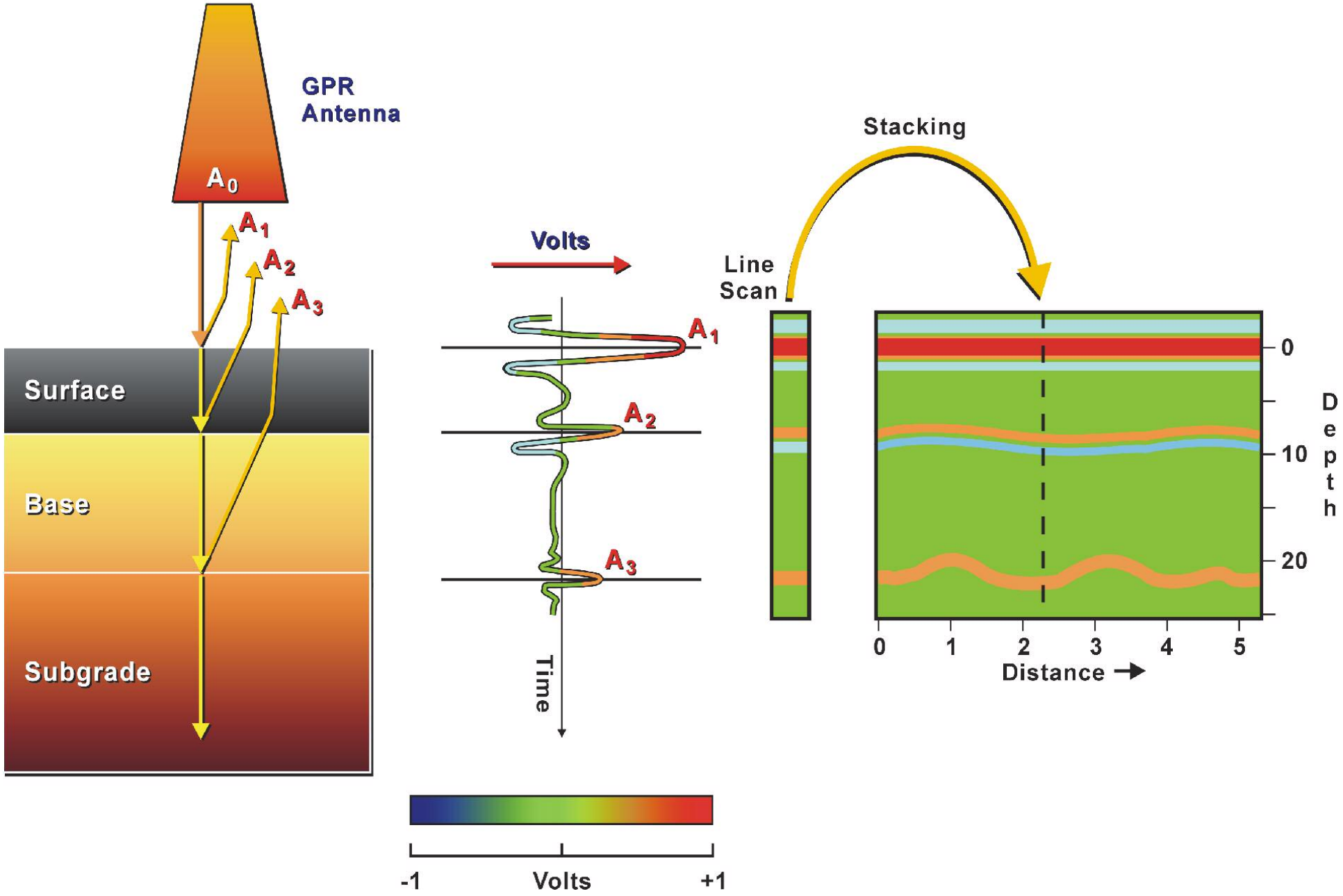
- Training schools available to introduce technology
- Data Reviewed and initial processing done in field
- Final Analysis for design project applications done by TxDOT Engineers
  - 5 experts within TxDOT

Engineering Significance of GPR Reflections



1. Surface Reflection A_0 (HMA Air Voids ↑ A_0 ↓)
2. Base Reflection A_1 (Base Moisture ↑ A_2 ↑)
3. Time Delay Δt_1 (Surface Thickness ↑ Δt_1 ↑)
4. Uniformity (Reflections at Interfaces Only)

Principles of Ground Penetrating Radar



Successful GPR Applications for Flexible Pavements

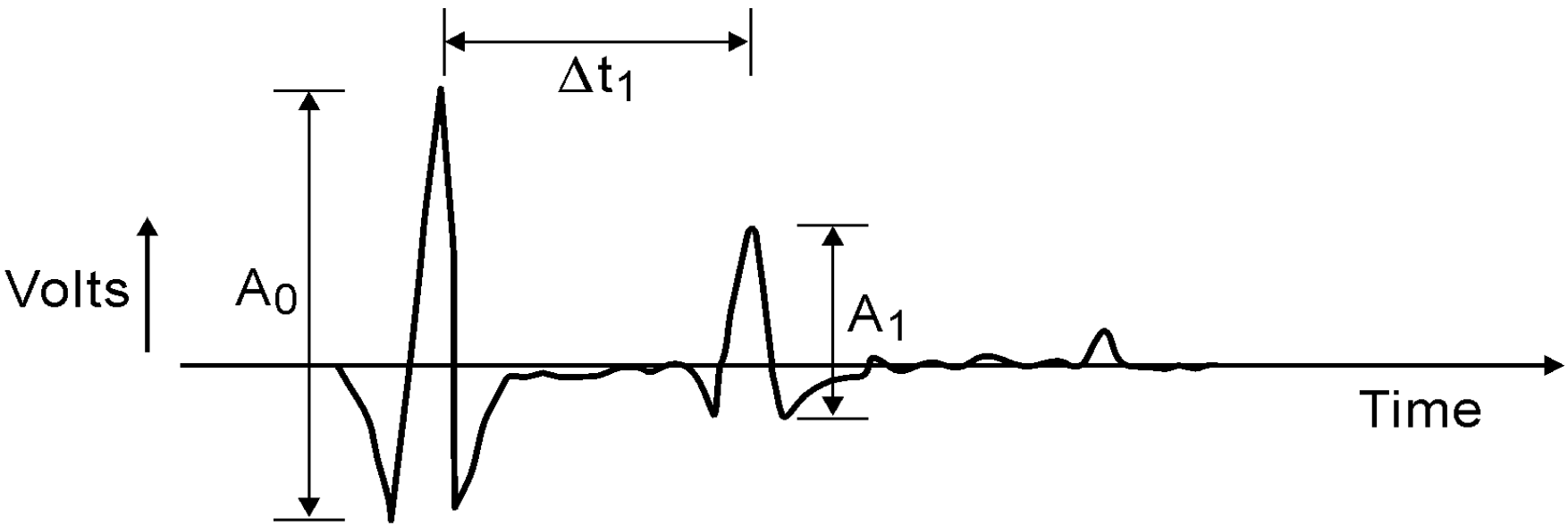
- Thickness of Pavement Layers
- Defects in Base (Wet areas)
- Defects in Hot Mix layers (stripping, trapped moisture)
- Identifying areas of segregation and poor joint density in new overlays
- Deterioration in asphalt covered bridge decks
- Pavement Rehabilitation studies (identifying changes in structure)
- Pavement Forensic Studies (cause of distress)

Limited success on concrete pavements

Does not work everywhere - oversold in some cases

Thickness of Pavement Layers

Engineering Significance of GPR Reflections



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GPR Thickness Accuracy vs Cores (Maser 1996)*

- New Asphalt (3 - 5%)
- Existing Asphalt (5 –10%)
- Concrete (5 – 10%)**
- Granular Base (8 – 15%)***

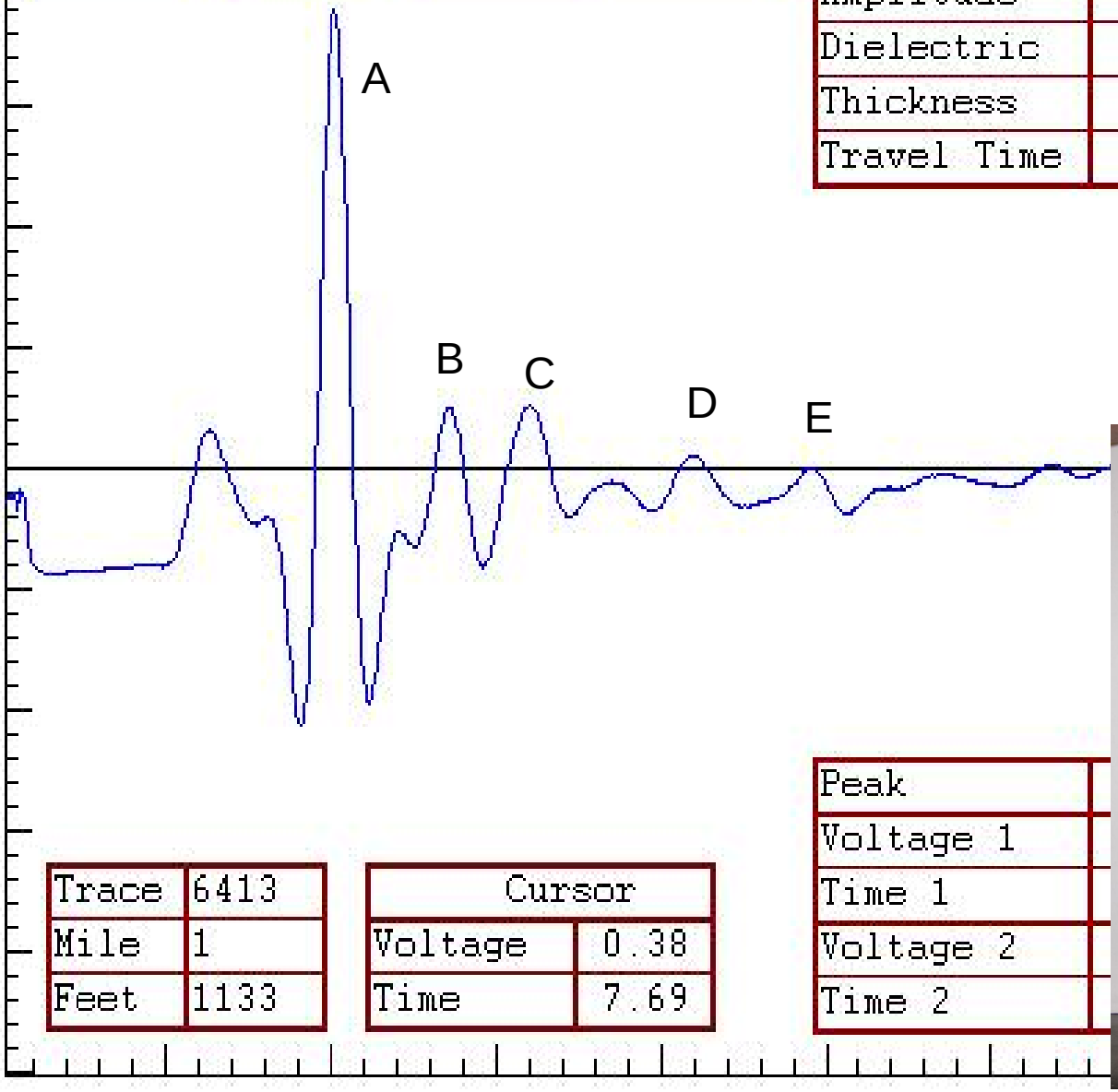
  - * 1 GHz air coupled limited to 24 ins
  - ** does not work for new concrete and requires adequate contrast between layers
  - *** requires contrast between base and subgrade

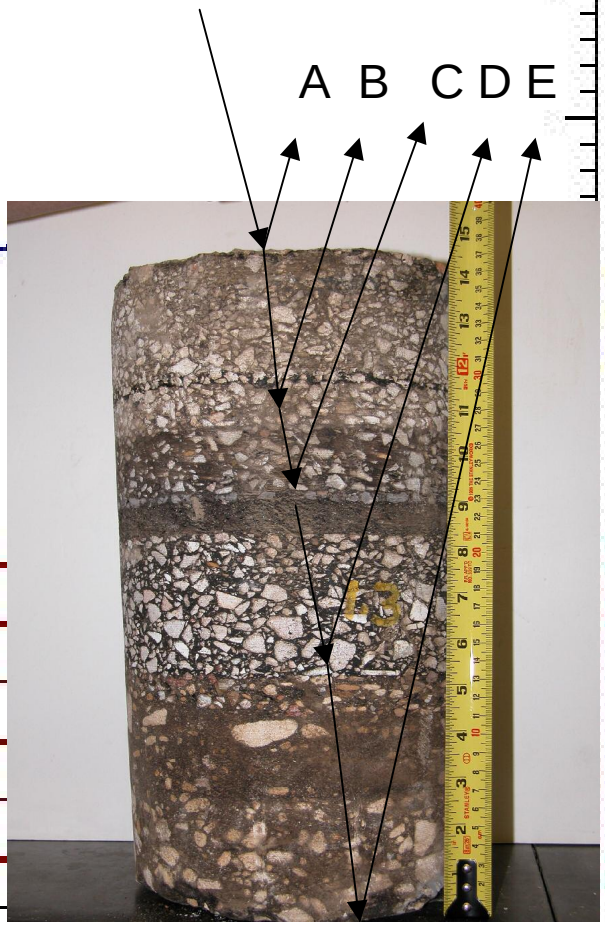
  - Validation core(s) very important on old sections

File Colormap Trace Process Display Options Compute REW Help

Compute | Undo | Prev. | Next

Layer	1	2	3	4
Amplitude				
Dielectric				
Thickness				
Travel Time				

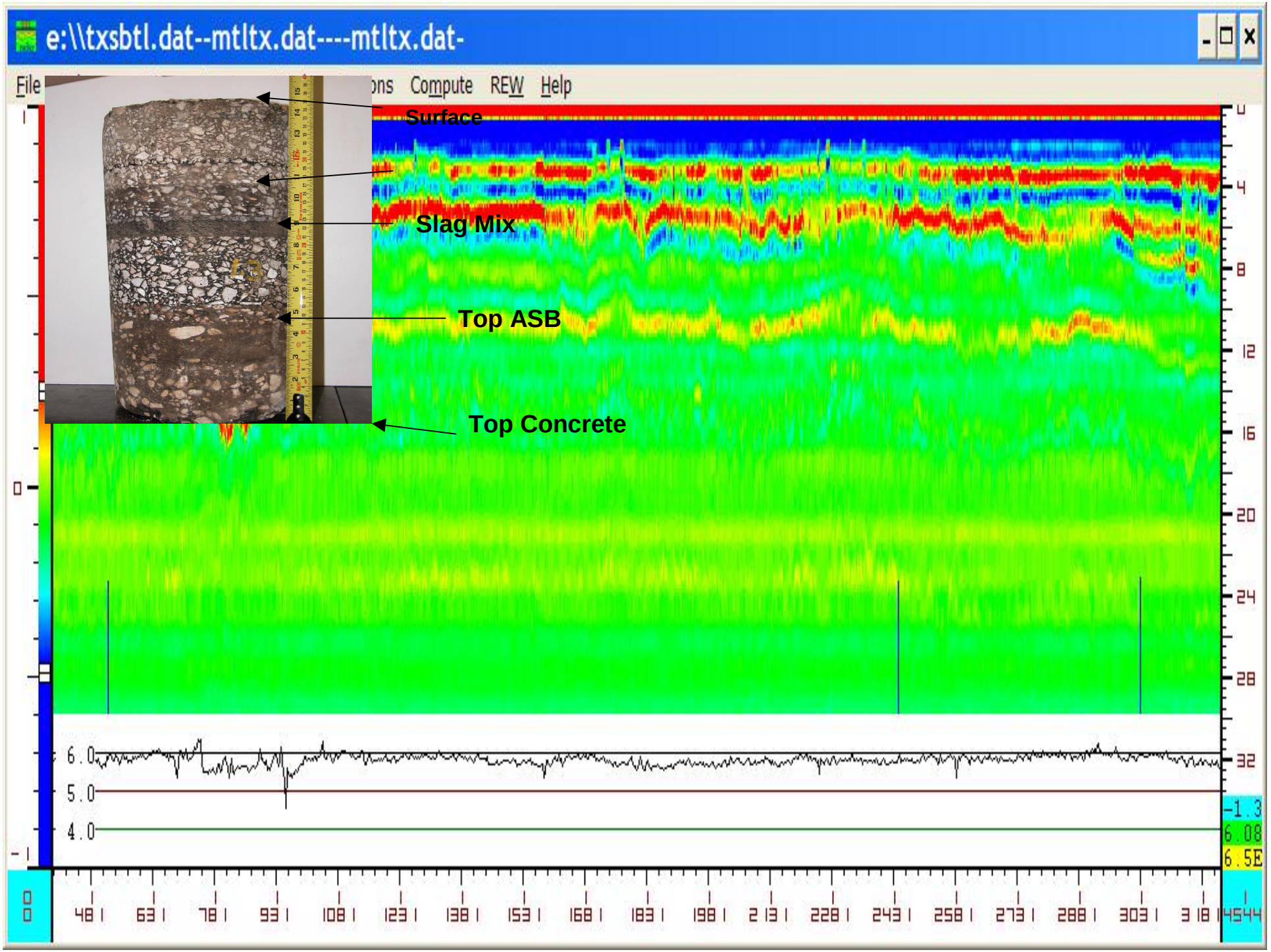




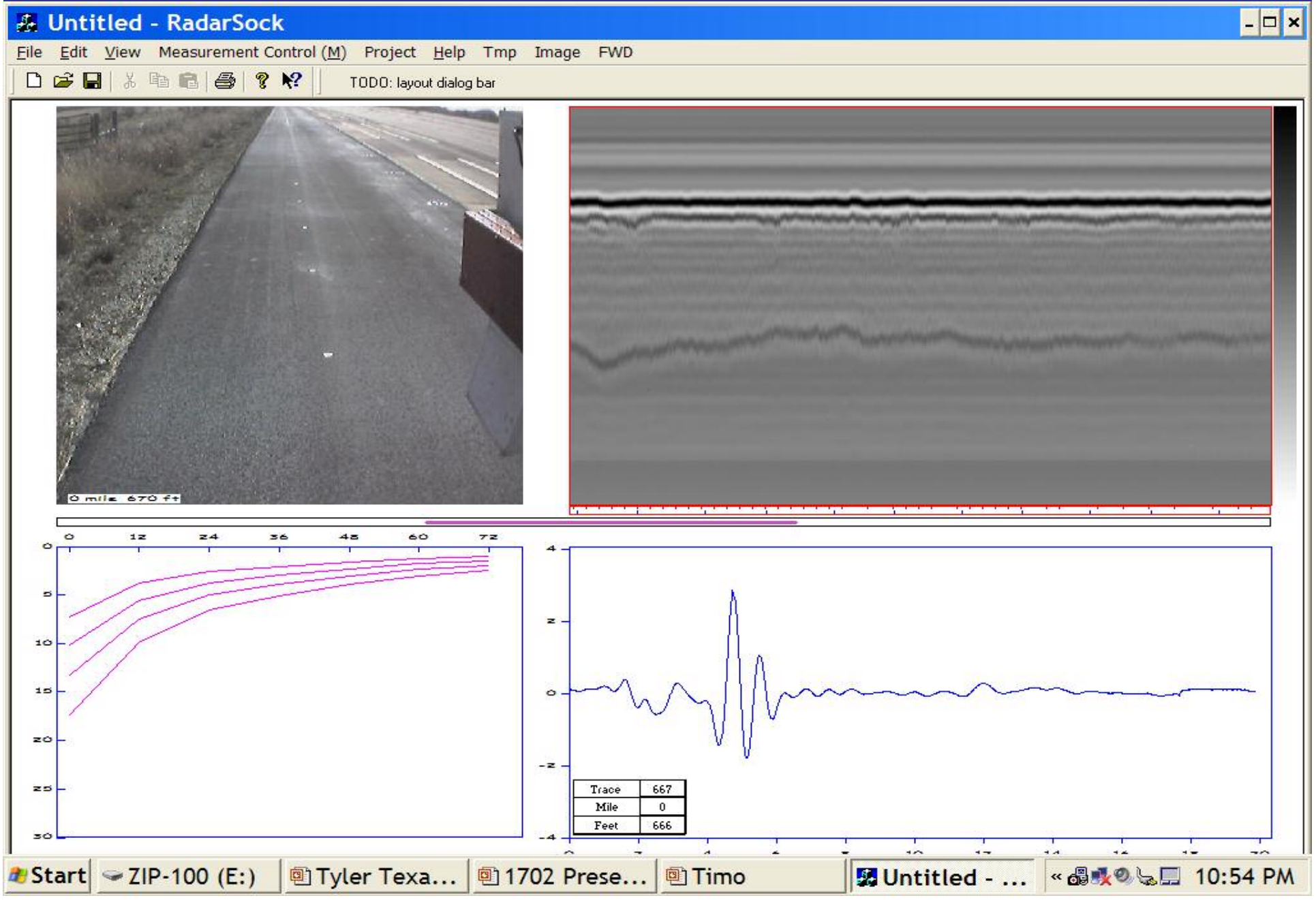
Trace	6413
Mile	1
Feet	1133

Cursor	
Voltage	0.38
Time	7.69

Peak
Voltage 1
Time 1
Voltage 2
Time 2


e:\\txsbtl.dat--mtltx.dat----mtltx.dat-
File
Compute
REW
Help
Surface
Slag Mix
Top ASB
Top Concrete
6.0
5.0
4.0
48
63
78
93
108
123
138
153
168
183
198
213
228
243
258
273
288
303
318
4544

Integration of COLORMAP and MODULUS 6

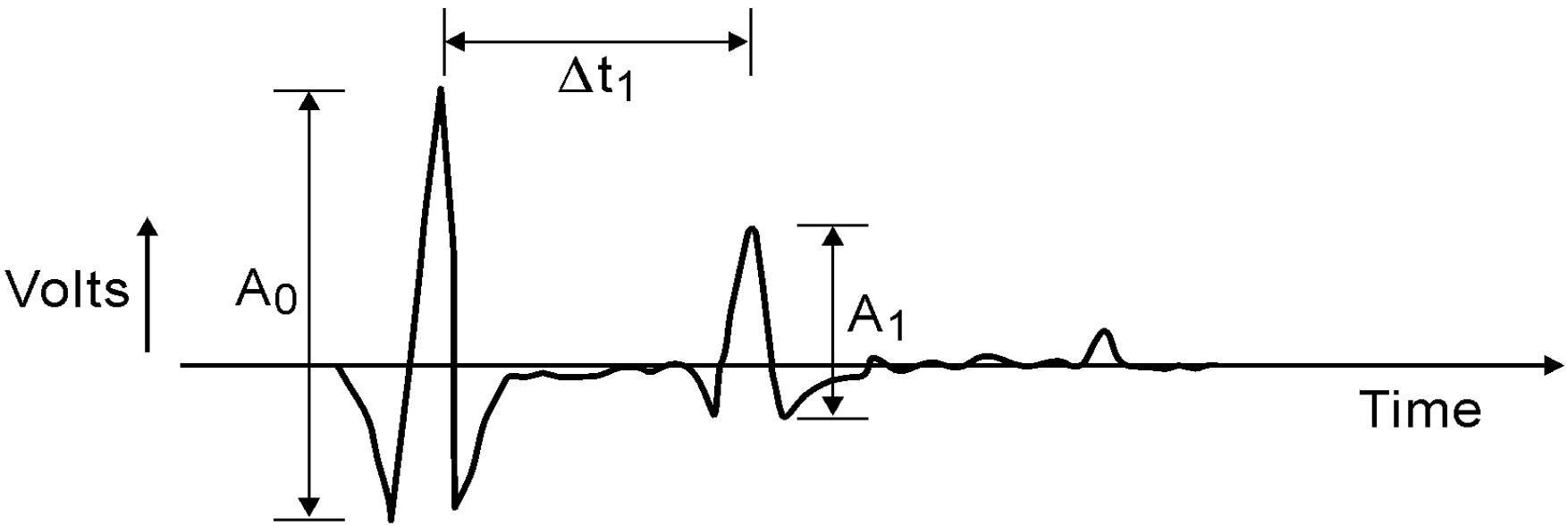


Moisture trapped within layers

In

Asphalt layers
Cement Treated bases
Rubblized Concrete
Under Concrete slabs

Engineering Significance of GPR Reflections



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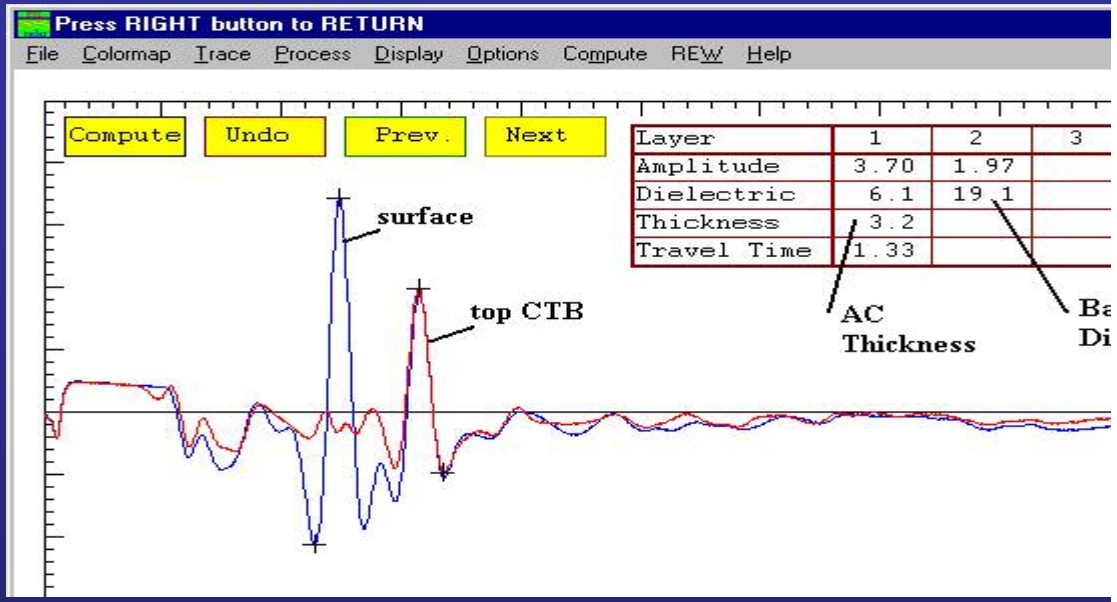
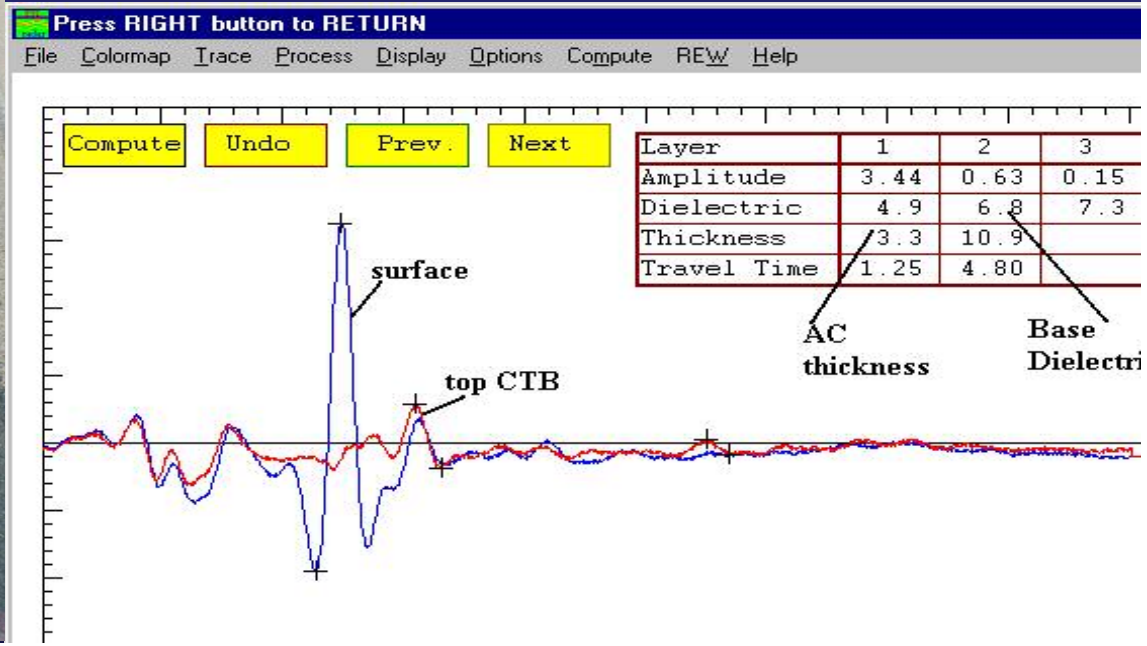
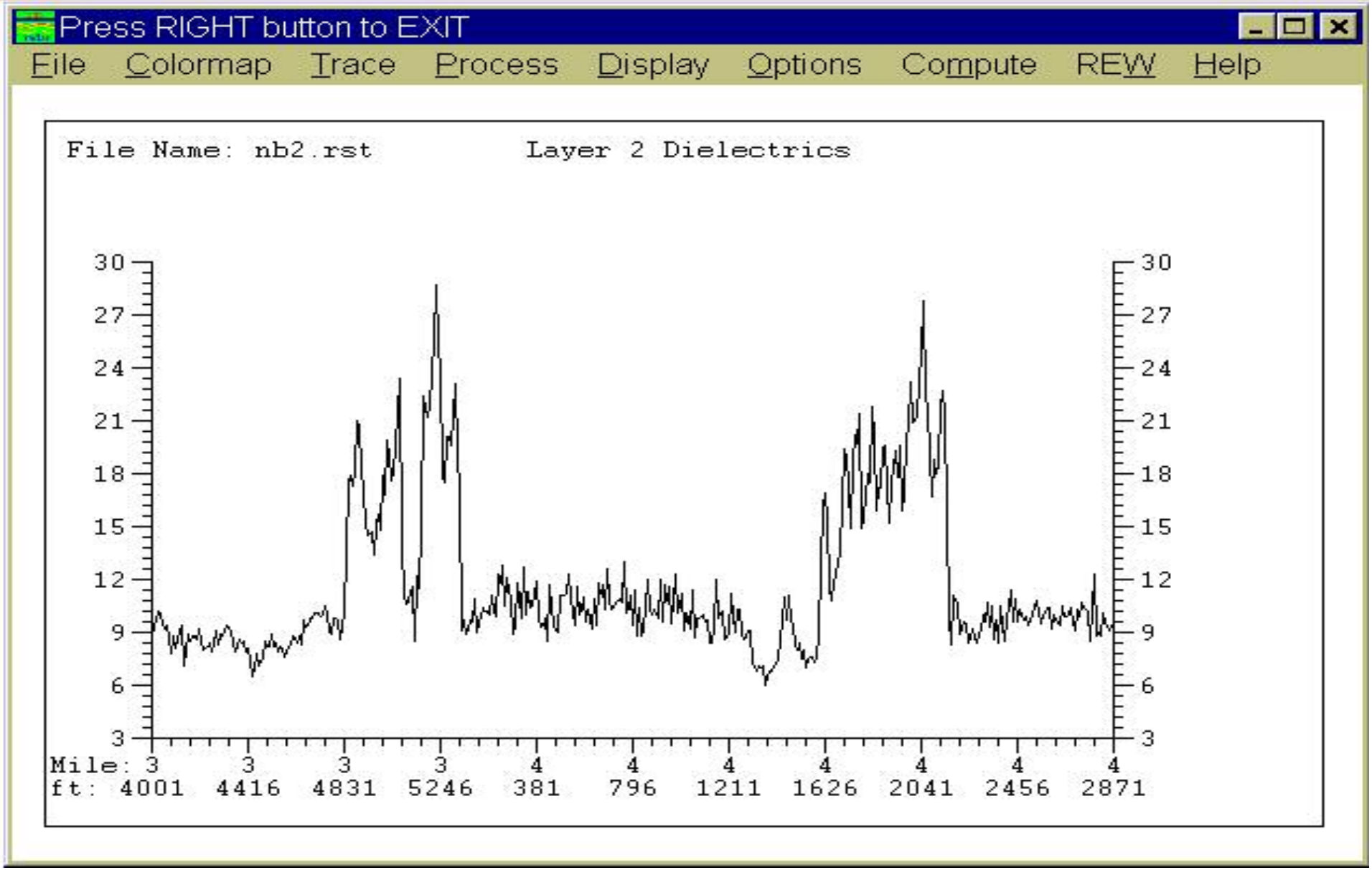
Detecting Base Moisture problems with GPR

3 Year old CTB
Sandstone
(Houston)





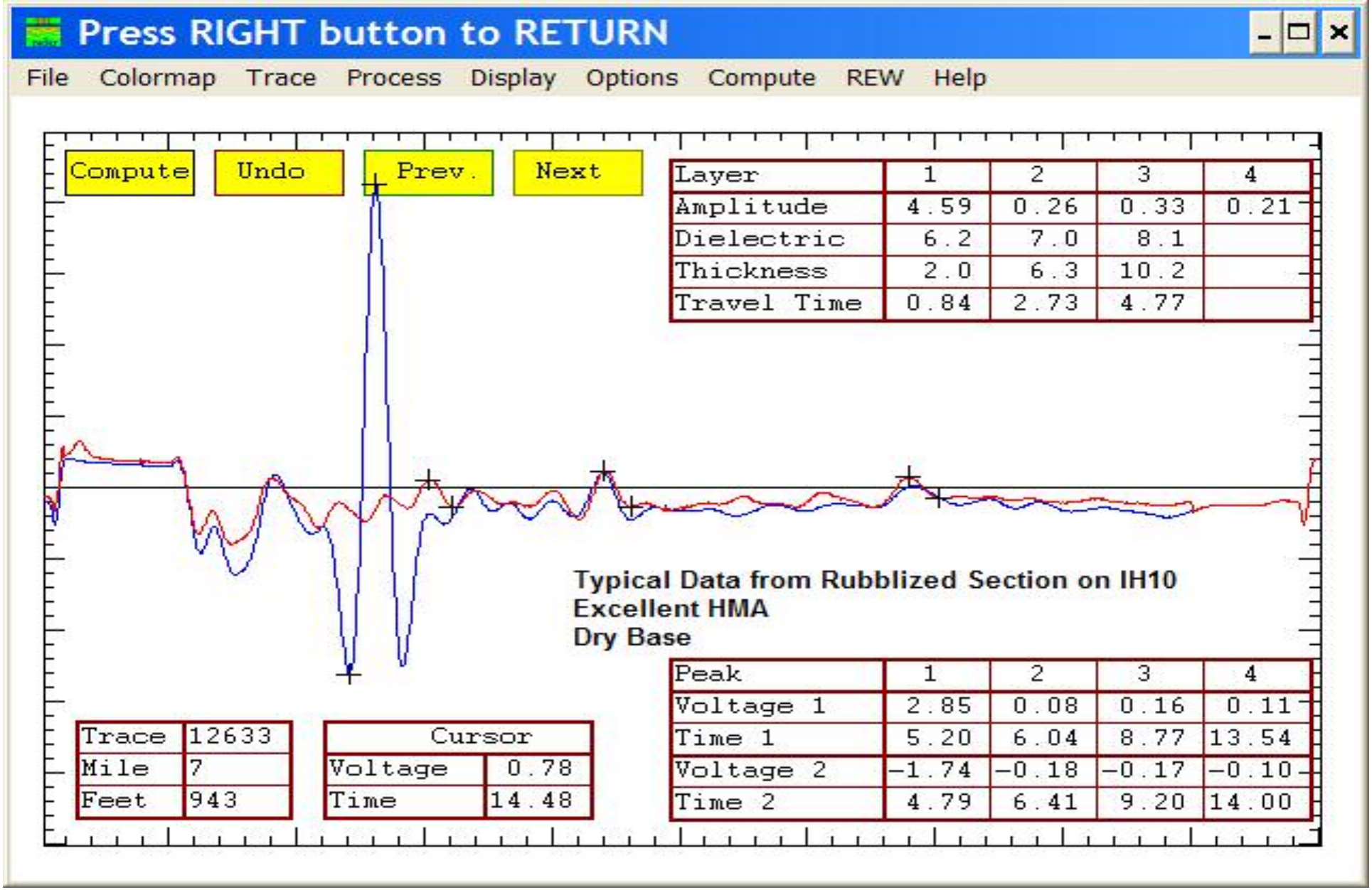
Base dielectric plot locating wet areas



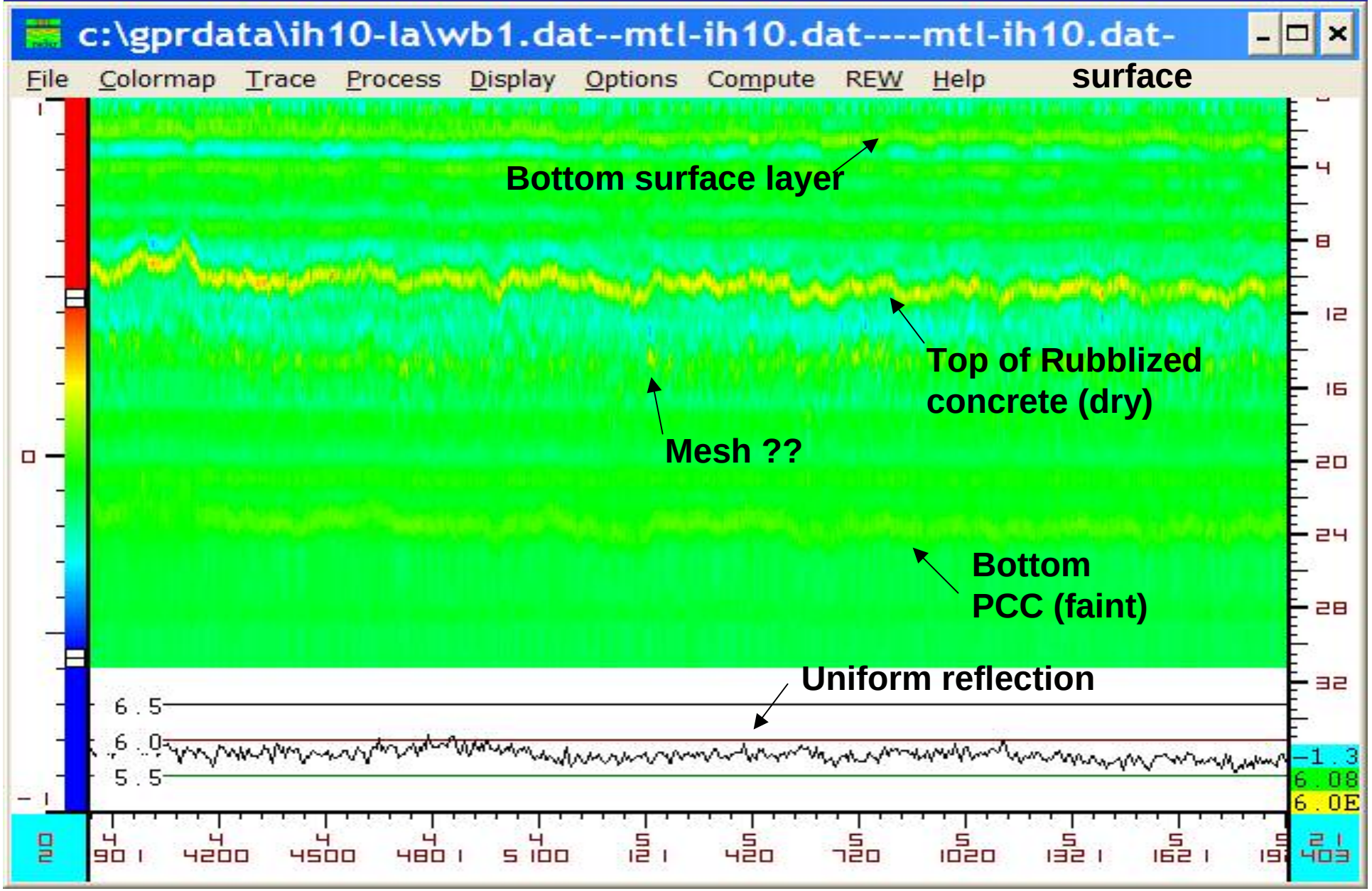
NDT Evaluation of Rubblized Concrete on IH 10 (1/30/03)

- Ground Penetrating Radar
  - Any moisture trapped in base
  - Any defects in HMA (trapped water, segregation, density problems in low layers, quality of joints)
- Falling Weight Deflectometer
  - Is the rubblized layer a granular base?
  - Moduli values for design for rubblized concrete and Superpave mix

IH 10 Ideal GPR trace 98% of project

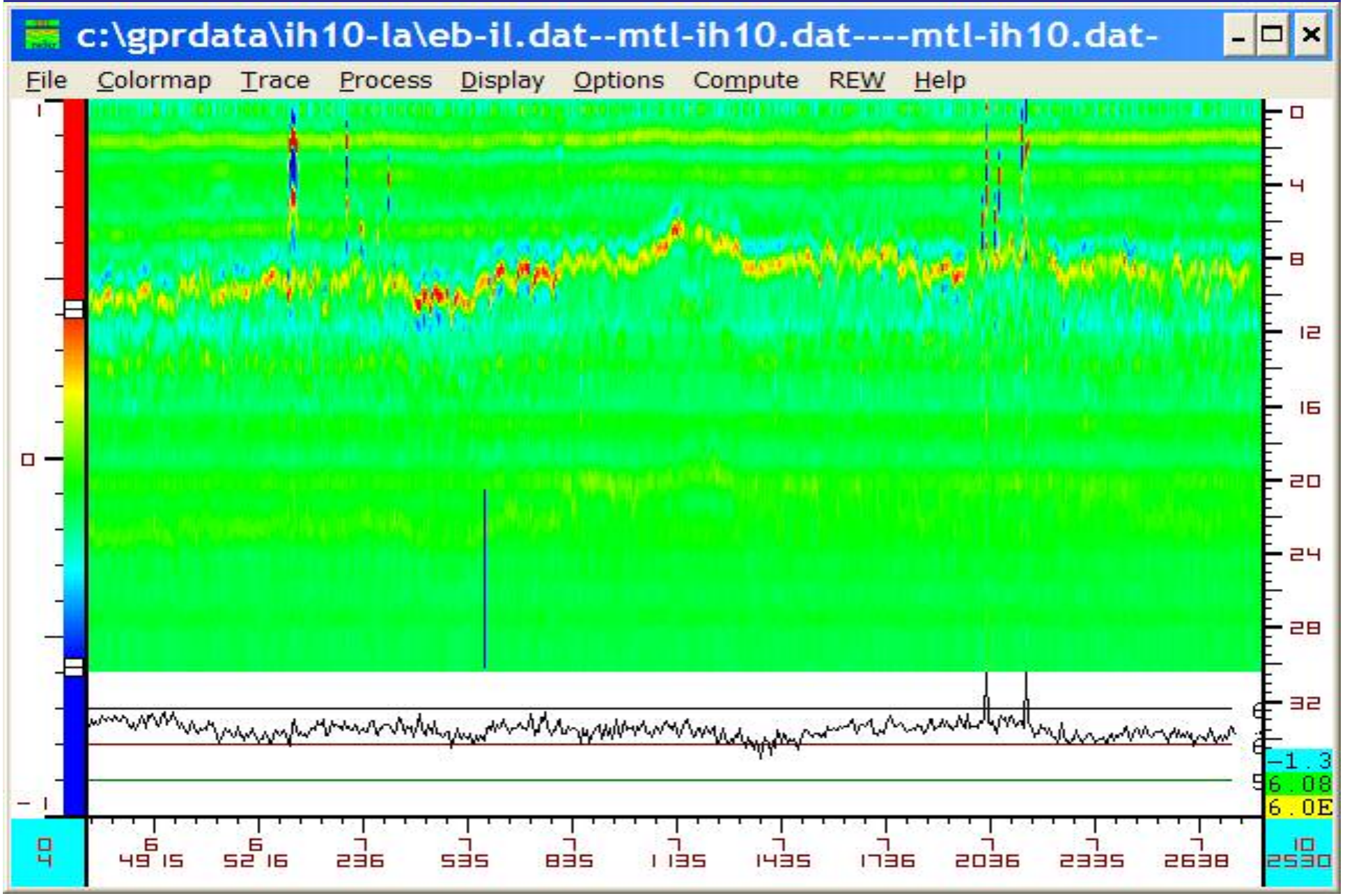


Ideal COLORMAP display EB

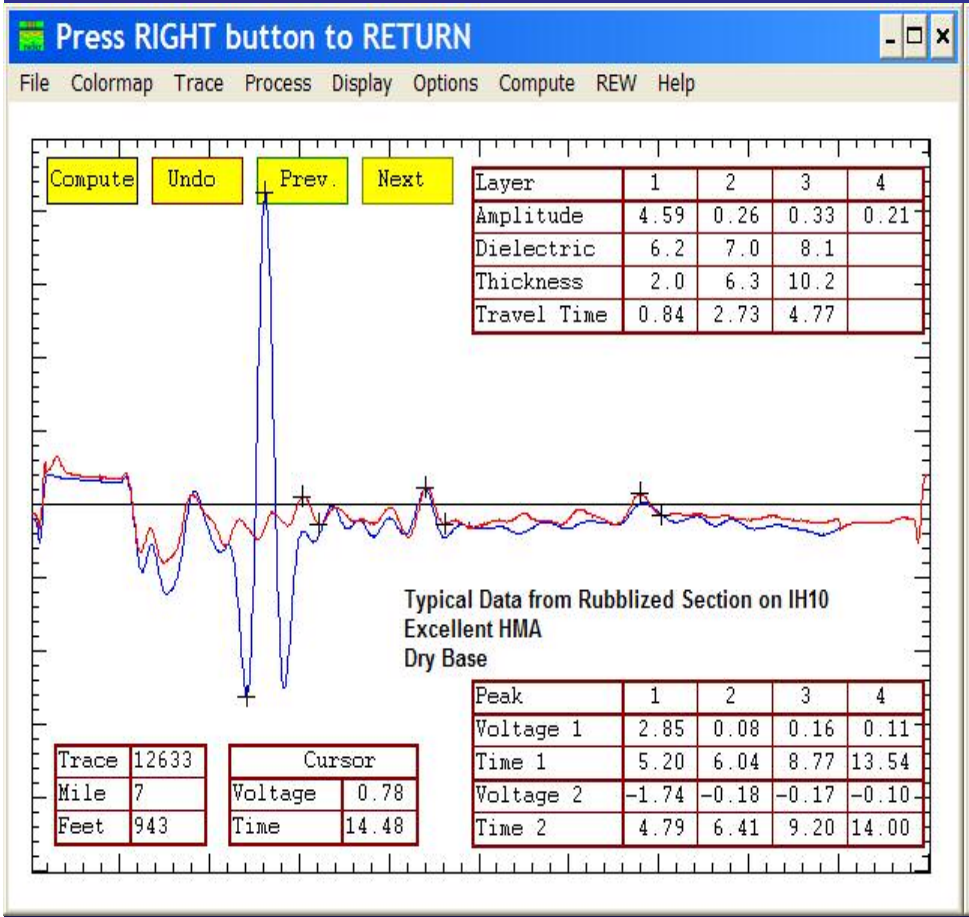



12195
6
4909
5

Defect areas (on-off ramps)



Wet layer 2 ins down

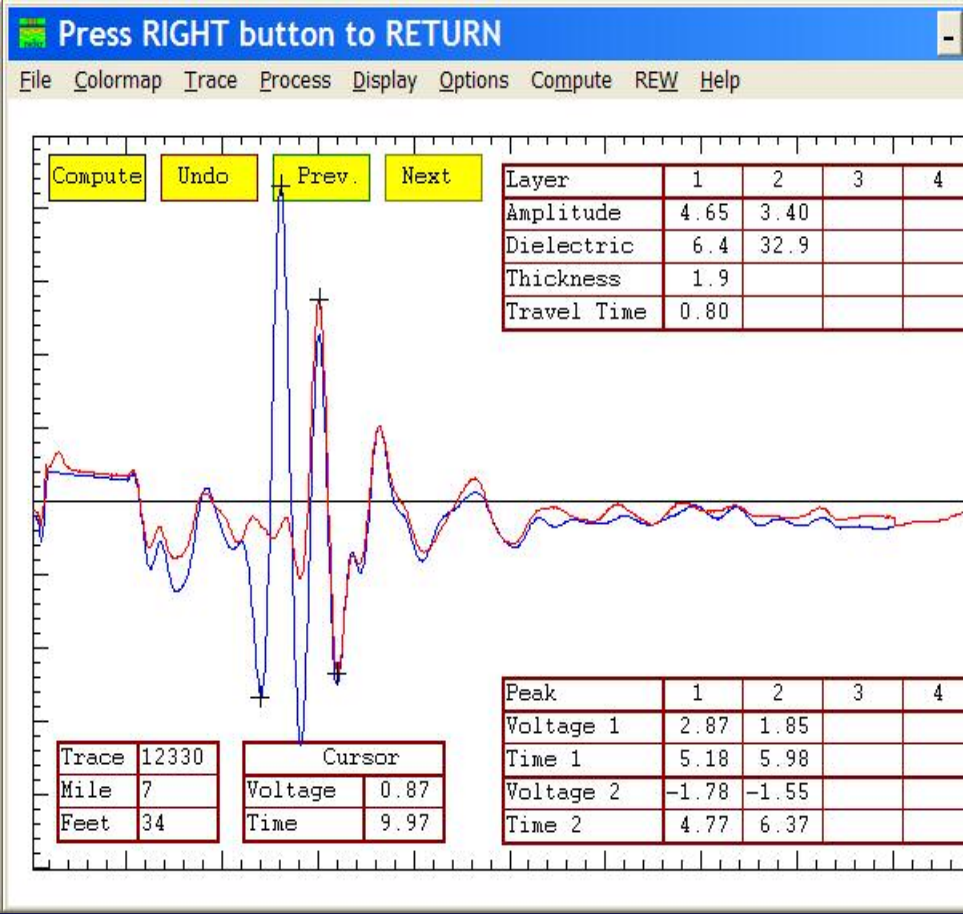


Layer	1	2	3	4
Amplitude	4.59	0.26	0.33	0.21
Dielectric	6.2	7.0	8.1	
Thickness	2.0	6.3	10.2	
Travel Time	0.84	2.73	4.77	

Peak	1	2	3	4
Voltage 1	2.85	0.08	0.16	0.11
Time 1	5.20	6.04	8.77	13.54
Voltage 2	-1.74	-0.18	-0.17	-0.10
Time 2	4.79	6.41	9.20	14.00

Trace	12633
Mile	7
Feet	943

Cursor	
Voltage	0.78
Time	14.48



Layer	1	2	3	4
Amplitude	4.65	3.40		
Dielectric	6.4	32.9		
Thickness	1.9			
Travel Time	0.80			

Peak	1	2	3	4
Voltage 1	2.87	1.85		
Time 1	5.18	5.98		
Voltage 2	-1.78	-1.55		
Time 2	4.77	6.37		

Trace	12330
Mile	7
Feet	34

Cursor	
Voltage	0.87
Time	9.97

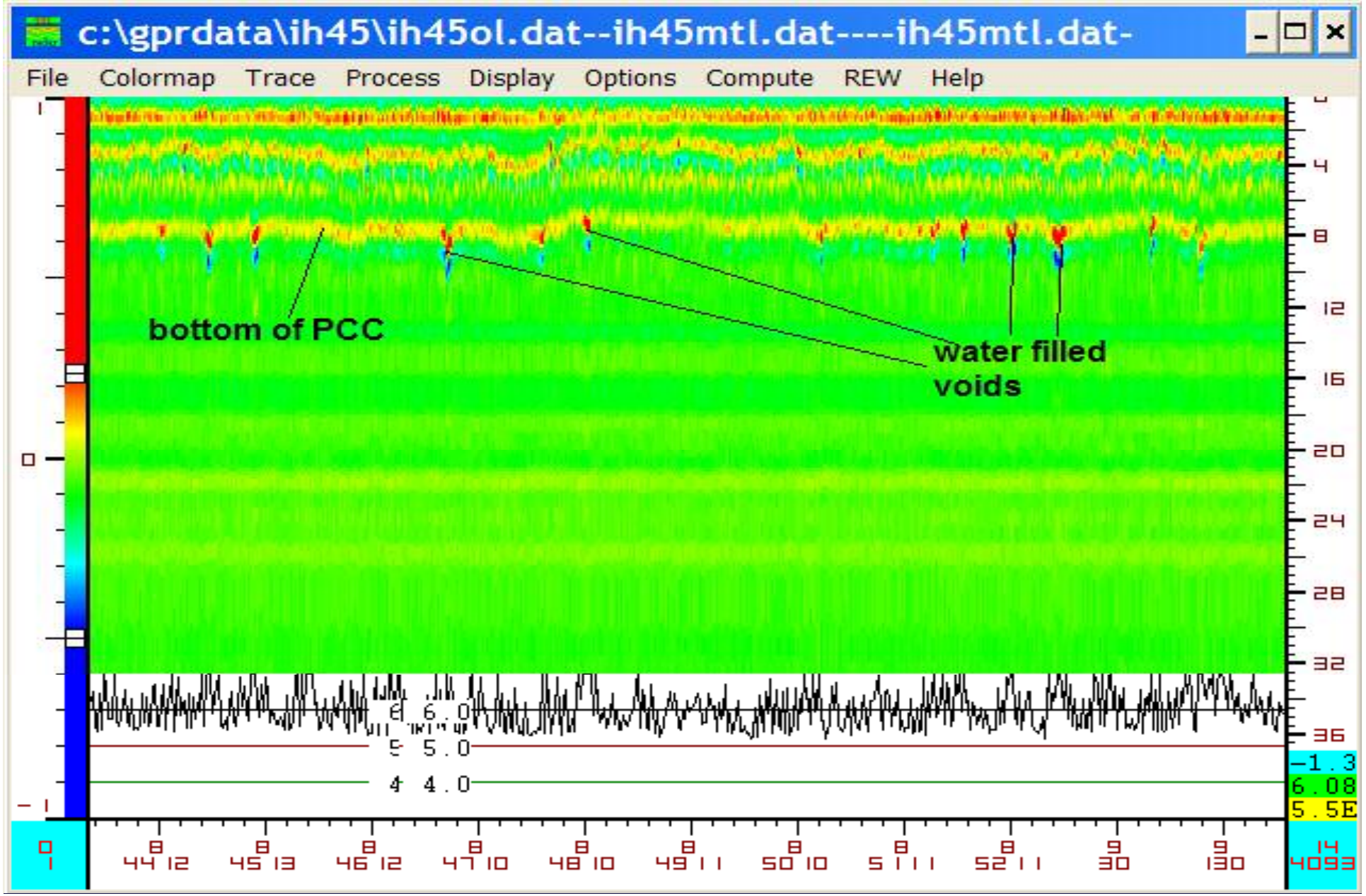
Normal Location

Defect Location


12330
MI
7
FT
32
MK
5
X

Candidate for Rubblization ??

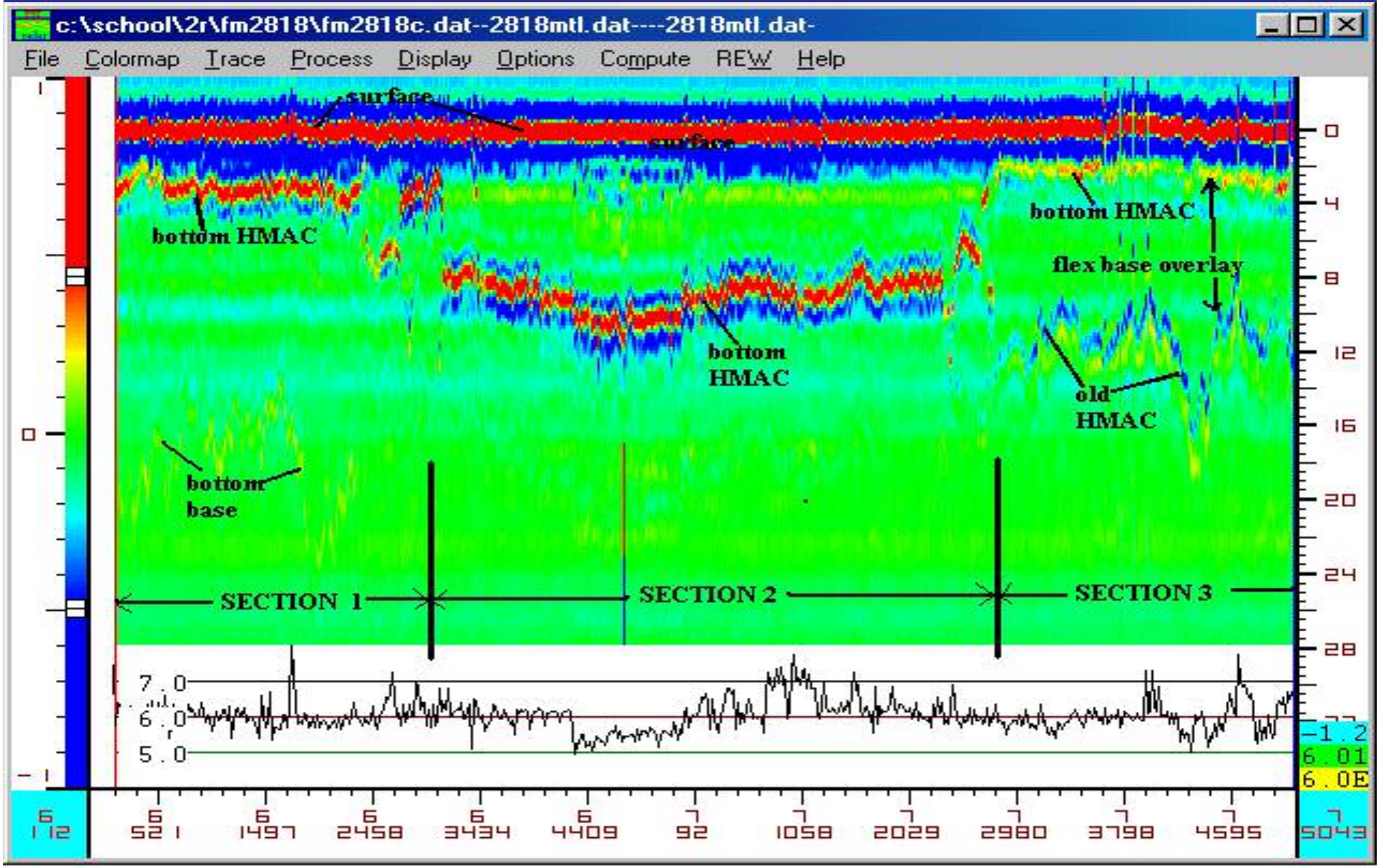
IH 45 NB Localized water filled voids beneath slab



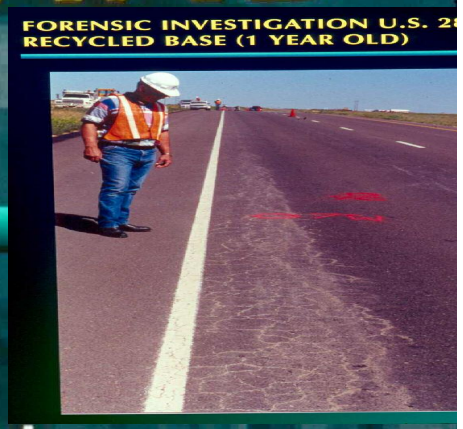
Forensic and Pavement Rehabilitation Studies

- Uniformity of section
- Thicknesses for FWD analysis
- Cause of Surface Distress

Use of GPR in Pavement Rehabilitation projects
Identifying section breaks with GPR



SELECTING REHAB OPTIONS



Adequate

- Distress
- Performance

Problem

Resurfacing

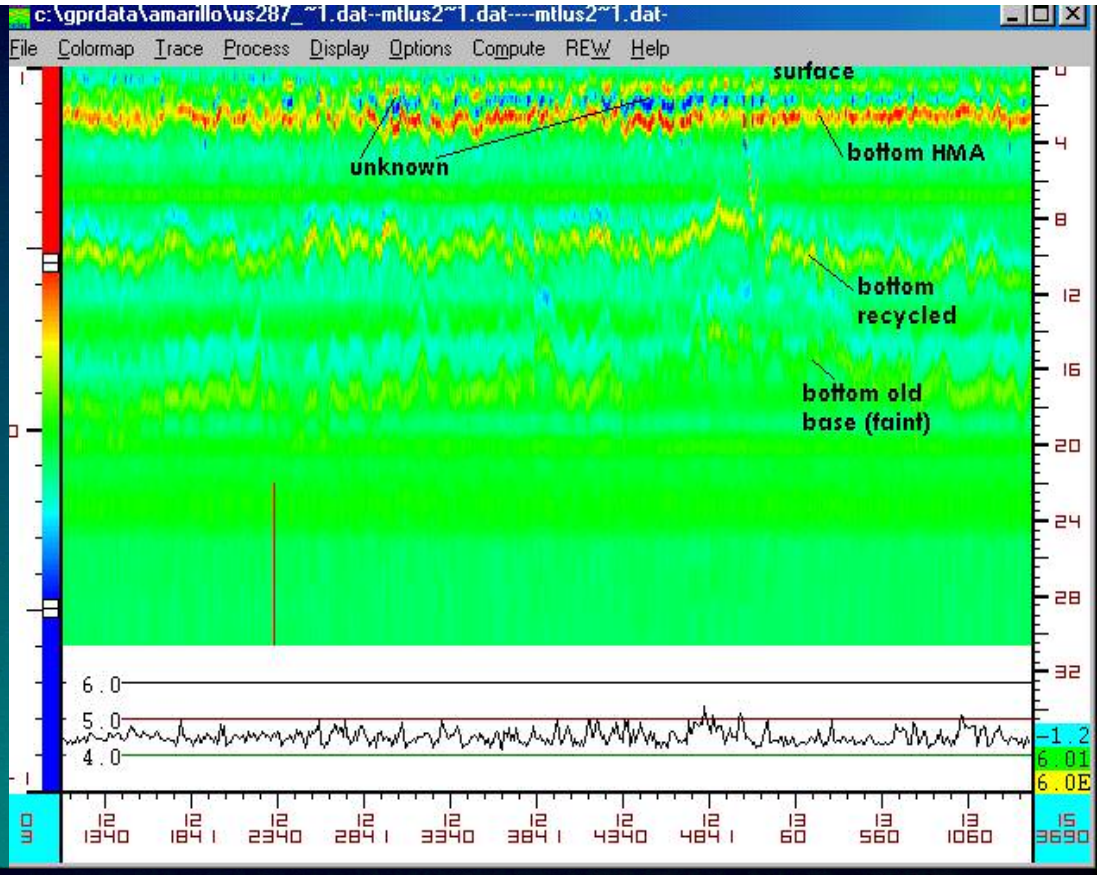
Find Out What's Wrong and Fix It

1) cause (proof) 2)what to do now? 3) How to avoid in future?

Pavement Evaluation Tools

Recommended Approach

- Step 1 Assemble Background Info
  - X-section, Age, Visual Condition, Best Guess
- Step 2 GPR Survey
- Step 3 FWD Survey
- Step 4 Propose cause of problem
- Step 5 Field Verification
  - DCP, Coring, Lab Testing
- Step 6 Generation Rehab options
  - Hold it together for 5 – 10 years
  - Fix the problem (structural design FPS 19
- Step 7 Engineering Report



Alligator 1 US 287

Causes of Failure

Lack of bond between HMA layers

Burnt binder in top layer

Not a base problem

FORENSIC INVESTIGATION U.S. 287 RESULTS FROM SHALLOW TRENCHING

Key Steps In Implementation

- In house (TxDOT)
- With expert consultants

Complete System for DOT implementation

- Good Equipment (TxDOT Specifications)
- Good Data Acquisition Software
  - 1024 bit resolution
  - Distance based data collection
  - Integrated Video
- Good Data Processing System
  - Thickness and dielectric computation
  - Handle thin surfacings
  - Handle vehicle bounce
- Research (what works / what does not)
- Training
- Maintenance support

Keys to TxDOT's implementation

- Long term development and implementation support
- Have reasonable expectations
- Get the technology onto high dollar projects (pavement rehab) and the information into the hands of decision makers
- Train key pavement designers in Districts
- Training Schools + CD's
  - 1.5 days school on GPR
  - 3 - 4 day school on Pavement Rehabilitation (project specific)

PROCESSING & INTERPRETING

Ground-Penetrating Radar DATA

CARL BERTRAND
TxDOT Engineering Specialist
Pavement Section — Design Division
Austin

GPR

can provide guidance in determining specific locations for coring, DCP testing,

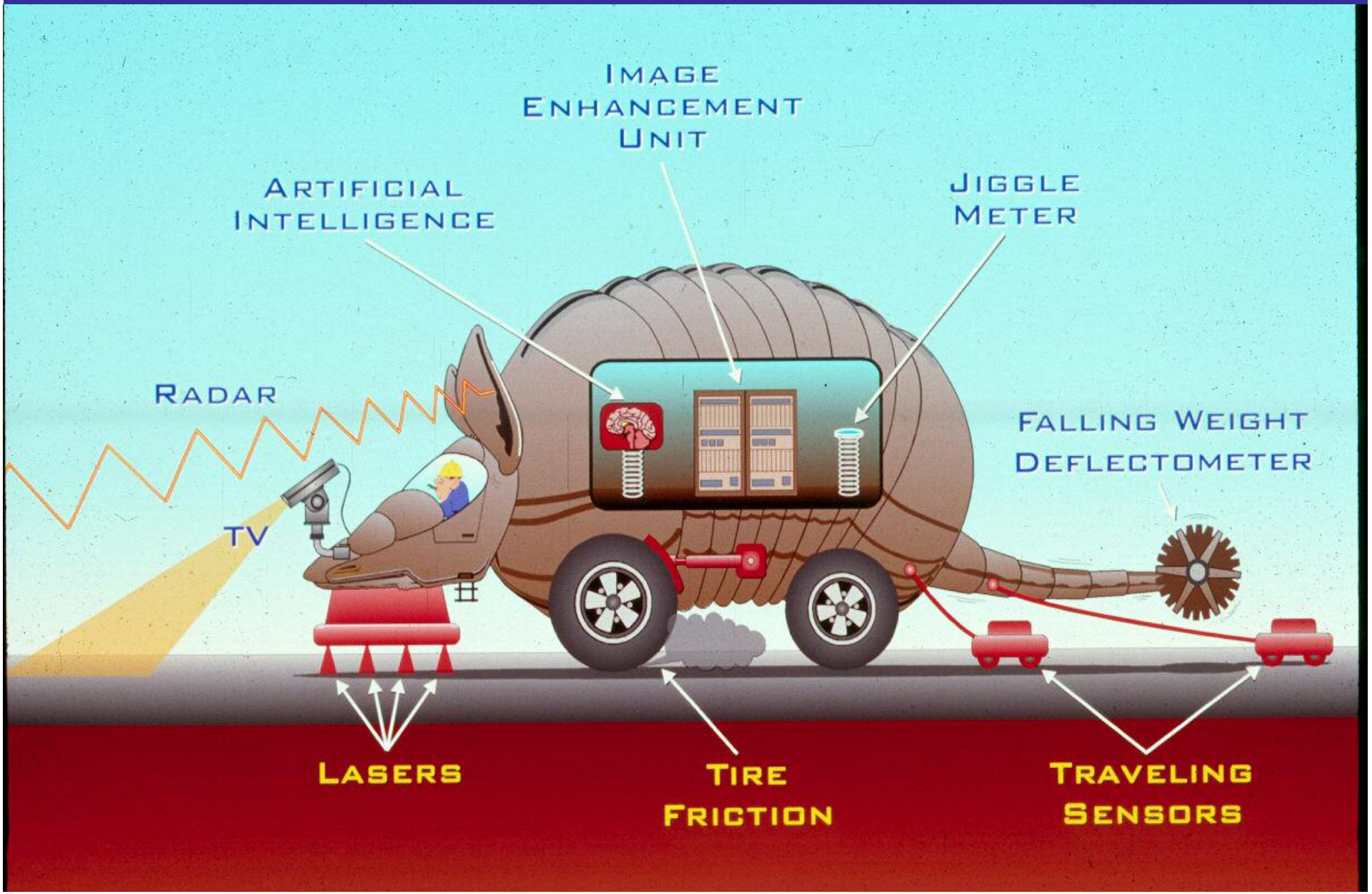
and other diagnostic tests

- Carl Bertrand intro.exe

Dealing with Consultants

- Oversell technology
  - Does not work everywhere
- Training for DOT personnel
  - Must know limitations of technology
- AASHTO involvement pp-40 and TIG
- Pilot testing - Absolute need for validation

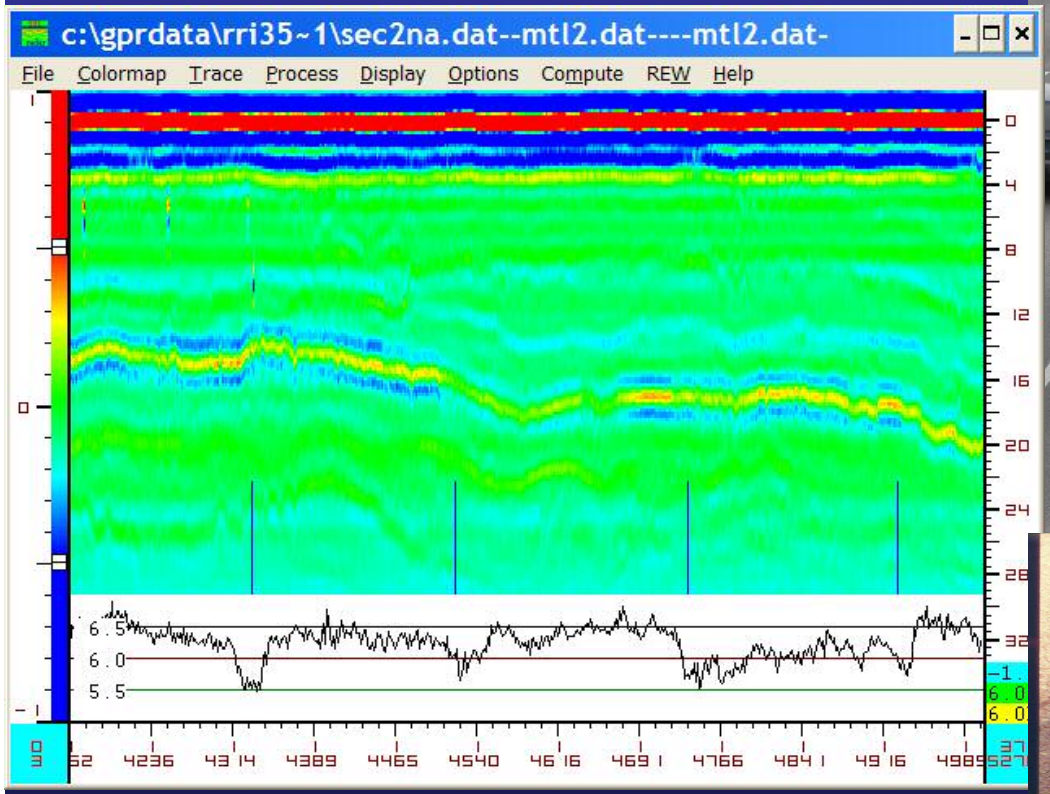
New Applications and Developments
Multi-Functional Vehicle (Texas Flavor)

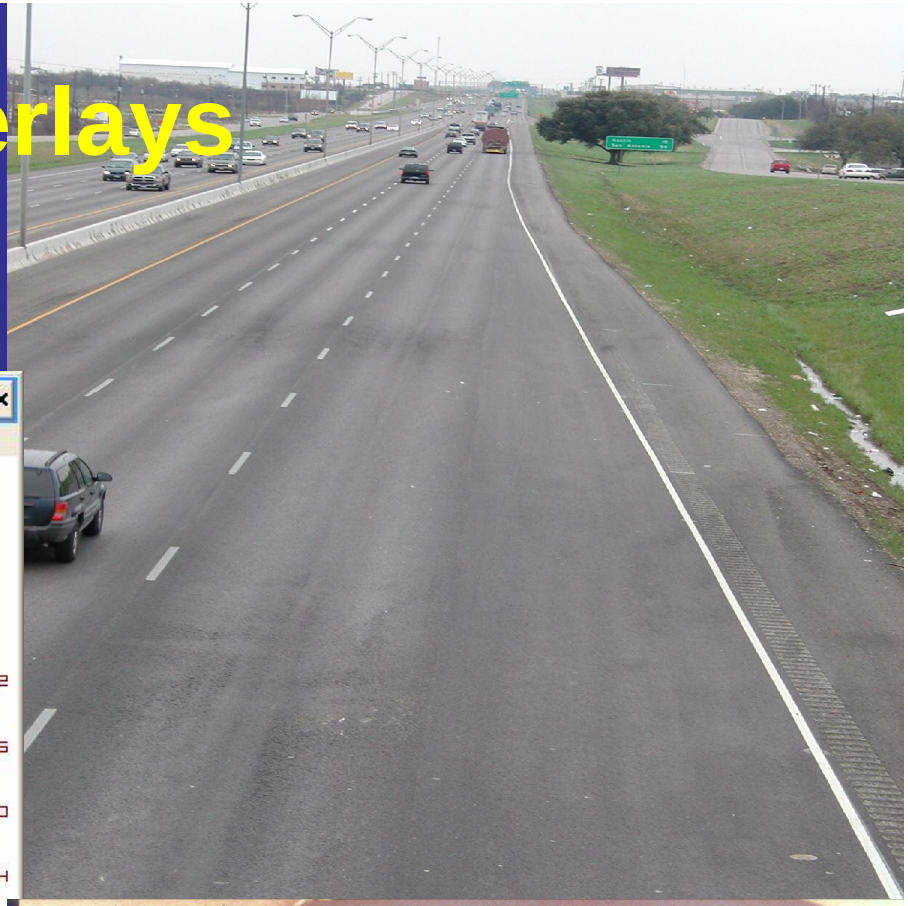


QC testing of new overlays

Segregation Detection

Longitudinal Joint Density





Changes > 0.4 out of spec on air voids for Dense Texas mixes

> 0.8 for Open graded mixes